MODIS Team Member - Semi-annual Report

Marine Optical Characterizations
December 2000

Dennis K Clark
NOAA/NESDIS

SUMMARY

Since the launch of NASA's TERRA satellite, the Marine Optical Characterization Experiment (MOCE) Team has continued to acquire and provide at-sea observations for MODIS initialization and calibration tasks. The Marine Optical Buoy (MOBY) system has been acquiring optical and basic meteorological observations coincident with TERRA's overpasses in support of the Moderate Resolution Imaging Spectrometer's (MODIS) ocean color mission. The match up database, produced with these coincident overpasses, are being utilized for the initial evaluation of the MODIS ocean spectral band calibrations and atmospheric correction parameters utilized in the retrieval of the radiances emanating from the ocean environment. During this period, the team conducted four field campaigns in Hawaii in support of the MOBY project. These cruises, designated MOBY-L58 through MOBY-L61, serviced the MOBY213 and MOBY214 instruments. A very successful Marine Optical Characterization Experiment (MOCE-7), which was focused on MODIS initialization, was carried out in Hawaii in December 2000. Team activities during the reporting period are shown in Figure 1. Also, the team is continuing to provide the SeaWiFS Project observations for their validation and long term calibration tasks.

During this period, a series of invited talks and posters featuring a number of the team's MODIS science endeavors (MOBY time-series, radiometric calibrations, bio-optical algorithms, and a fiber optic spectrometer) were presented at four scientific symposiums (Figures 2, 3, and 4). Also, the team hosted an open-house for the IGARSS 2000 conference at the MOBY operations site.

FIELD OPERATIONS

MOBY-L59 (M218SOB)

The MOBY-L59 recovery and replacement cruise took place August 3 - 6, 2000 aboard the Research Vessel (R/V) Ka'imikai-o-Kanaloa. The following personnel participated:

NOAA - Dennis Clark, Edwin Fisher, Eric Stengel, Yong Sung Kim, Mike Ondrusek

MLML - Mark Yarbrough, Mike Feinholz, Darryl Peters, John Heine

HRA - Steve Juarez, Earl Keatley, Fran Keatley, Fred Kokesh

MOBY214 was successfully deployed at the Lanai mooring site on August 3, and crossover optical profiles with MOBY 213 and 214 were acquired on August4. MOBY213 was recovered on August 5. Optical measurements via Marine Optical System (MOS), Fiber Optic Spectrometer (FOS), SeaWiFS Profiling Multichannel Radiometer (SPMR), and Surface Irradiance Spectrometer (SIS) were made at the MOBY mooring site on August 5 coincident with MOBY214 observations and the SeaWiFS overpass. Diver calibrations of MOBY214 were performed with the assistance of Hawaiian Rafting Adventures. MOBY213 was disassembled, cleaned, and calibrated after the cruise.

MOCE-7

MOCE-7 occurred December 3- 10, 2000 aboard the R/V Ka'imikai-o-Kanaloa. The science party personnel and affiliations for MOCE-7 are listed below.

NOAA - Dennis Clark, Edwin Fisher, Eric Stengel, Marilyn Yuen, Yong Sung Kim, Larisa Koval, Mike Ondrusek

MLML - Mark Yarbrough, Mike Feinholz, Darryl Peters, Rachel Kay, Stephanie Flora, John Heine, Terry Houlihan

CHORS - Chuck Trees, Chris Kinkade

University of Miami - David Bates, Ken Voss, Albert Chaplin

The cruise objectives were to continue our quarterly MOBY/MOS refurbishment cycle and to provide radiometric characterizations and spatial variability of water-leaving radiances and atmospheric transmittances concurrent with MODIS and/or SeaWiFS observations. MOBY214 was retrieved and the new MOBY215 was deployed at the beginning of the cruise (Fig. 5). The MOBY buoy upper arm has suffered damage during the past few MOBY deployments. We now have evidence that the damage is due to the MOBY buoy colliding with the Mooring float. The damage to the upper arm matches damage found on the Mooring float underside and subsurface frame. Red anti-foulant paint from the Mooring float was found on the upper arm of MOBY in the damaged areas. The MOBY upper arm had apparently become caught in the frame area on the underside of the Mooring float as the buoys passed by each other during a period of low winds and little current. The lower frame will no longer be deployed as a part of the Mooring float. Hopefully, the buoys can pass by each other without damage if the frame is not there to trap the MOBY arm. A new, smaller framework will be built to mount underwater instruments.

Based upon the success of the initial deployments of the drogue style flopper stoppers, longer drogues were used with the MOBY215 deployment. The new drogue strings are 50 meters long, about the maximum practical length. The wire bridle was shortened to 10 meters to accommodate the extended length drogues. The improvements to the mushroom anchors seem to be effective in reducing damage to the lower portion of the drogue array. The anchor depth is 70 meters with this arrangements.

A complete suite of measurements, designed to characterize the bio-optical state, were performed at seven stations during satellite overpasses. SeaBird CTD, SPMR, MOS and FOS casts were conducted at most stations (Appendix 1). Figures 6 and 7 show MOS and FOS instruments deployments. Figure 8 depictes SIS instrument operation. CTD casts and alongtrack water collection resulted in 60 TSM/POC/PON samples, including sample replicates at each satellite overpass. Additionally, 33 oxygen samples were collected and processed during the cruise to validate the CTD oxygen sensor data. The number of absorption spectra collected and analyzed during MOCE-7 were 123 particulate/detrital absorption samples and 119 colored dissolved organic material (CDOM) samples. During the cruise, 191 HPLC pigment samples and 196 fluorometric pigment samples were collected. Hand Held Contrast Reduction Meter (HHCRM) measurements, to derive the spectral transmittances, specifically bracketed each overpass. Water vapor column, ozone column, and aerosol optical depth were measured using MICROTOPS II during each overpass. The observations acquired provided a variety of marine optical, atmospheric, and biological signals for algorithm development, calibration and validation purposes.

INSTRUMENT CALIBRATIONS

MOBY

During this reporting period, MOCE Team members and professional divers conducted three calibration excursions via Hawaiian Rafting Adventures (HRA) chartered dive boat to perform the diver calibrations (MOBY-L58, MOBY-L60, and MOBY-L61). During the MOBY-L58 (July 18 - 20), Meteorological station (MET) maintenance was performed and MET data were downloaded. Water samples were collected and filtered for CHORS pigment analysis. MOBY213 optical sensors were cleaned and diver lamp calibrations were performed after the cleaning. During the MOBY-L60 service cruise (September 11 - 15), HRA divers inspected MOBY214 and took underwater photos - no problems were noticed (Fig 9). A new recalibrated CIMEL instrument was installed at the Lanai site. MET and MOBY calibration data were downloaded, MOBY sensors were cleaned and diver calibrations were performed. During the MOBY-L61 cruise (October 4 - 6), MET station data were downloaded, MOBY214 collectors were cleaned, and underwater photos were taken. A cable was replaced on the CIMEL instrument.

RADIOMETRIC STANDARDS & RADIOMETERS

Team personnel stationed at the NOAA operations facility at Snug Harbor, Hawaii continued to maintain NIST-traceability on our radiometric standards and perform calibrations of our radiometers. During this reporting period, radiometric calibrations of MOBY were performed before and after each field deployment using NIST-traceable standards of radiance and irradiance. The stability of our spectral standards of radiance and irradiance were based on calibrations by the manufacturers at regular intervals. The Gamma Scientific GS5000's Kinematic-mount power attachments were modified from original Gamma configuration in an attempt to solve an "arching" problem which was leaving carbon deposits on the positive FEL lamp post. Standard Lamp Monitor (SLM) scans of FELs after the modification showed an increase in 412 nm irradiance of about 1% - more in accordance with levels observed before the arching problem was discovered. Two FEL lamps, F454 and F471, are ready to be returned to NIST for recalibration. Mike Feinholz worked with B. Carol Johnson from NIST and Robert Barnes from NASA/GSFC in compiling our historical SLM scans to document the stability of our radiance and irradiance standards used during the MOBY calibrations - these results were presented as poster/papers at the "Oceans from Space" symposium in Venice, Italy in October 2000. Pre-deployment calibrations were performed on MOBY213 and 215 and post-deployment calibrations were performed on MOBY213 and 214. During this reporting period MOS instrument calibrations included # 202, 204, and 205. Our Surface Irradiance Spectrometer (SIS) and the Fiber Optic Spectrometer (FOS) were also calibrated before and after each field campaign. Appendix 2 provides detailed listings of calibrations and maintenance for each standard and instrument.

PIGMENT PROTOCOL EXERCISE

In August, CHORS personnel participated in the SIMBIOS/HyCODE chlorophyll *a* round robin exercise which was being coordinated by Laurie Van Heukelem of Horn Point Laboratory, University of Maryland. The objective was to identify factors causing divergence between HPLC and fluorometric measurements of chlorophyll *a* in natural samples. They agreed to participate only in the fluorometric portion of this round robin because the HPLC procedure for this exercise had the following deficiencies:

1. Known HPLC standards were to be sent to the various laboratories prior to the analysis of the unknown samples, thus minimizing the uncertainty between laboratories.
2. Replicate natural samples were to be collected and circulated between laboratories to document water mass difference between HPLC and fluorometric analysis without documenting the uncertainty in sample collection, filtration and preservation.
3. The participants and their results were to be kept confidential, except to the SIMBIOS Project.

Six chlorophyll *a* standards for fluorometric calibration were shipped to CHORS in July 2000. These standards were to provide 6 calibration levels for the fluorometer ranging from around 1.0

mg m^{-3} to greater than 200 mg m^{-3}. In addition, 3 unknown chlorophyll *a* standards were also shipped for analysis. The CHORS fluorometer was first calibrated, using our own chlorophyll *a* pigment standard (Sigma Chemical Co.) then the known pigment standards were analyzed. The average percent difference between our calculation of the concentration of the 6 unknown standards was 2.6% ± 4.5%. The largest uncertainty was found for Standard #6 (11.5%), which was the standard with the lowest concentration. Depending upon the results of the other laboratories, this standard maybe in error. If this standard is removed from the exercise, then the average percent uncertainty for CHORS was 0.77% ± 1.2%. Three unknown fluorometric samples were also analyzed. The results from this intercalibration effort is still pending the distribution by L. Van Heukelem of the comparison between other laboratories. In addition to the fluorometric unknowns, one spectrophotometric unknown was analyzed. A phone conversation with L. Van Heukelem indicated that we agree well with her estimates of the chlorophyll *a* concentration of the standard.

CIMEL SERVICE

The Lanai CIMEL site is still inoperable. CIMEL #93 was returned to GSFC for recalibration and refurbishment in July 2000. The radiometer was returned to us on September 11 but it was missing the robot control cable. The instrument was reinstalled at Lanai on September 13 during our previously scheduled MOBY/CIMEL trip. The missing cable arrived from GSFC the following week. During MOBY-L61, the cable was installed and the unit was activated. Upon starting the instrument, the “refurbished” robot would not operate properly. The unit was left deactivated at the site. We still have the original robot and we will reinstall it as soon as possible.

The Coconut Island site has operated properly since the replacement of the malfunctioning GEOS transmitter unit. The transmitter was replaced during the MOBY-L61 service expedition. The unit had been dropping 3-5 messages daily during the afternoon hours. We continue to service the site on a biweekly basis.

DATA PROCESSING

MOBY

MOBY continues to acquire and transmit two files per day, coincident with SeaWiFS and MODIS overpass times. MLML personnel process these files and make the data available on our MOBY home page the day after transmission. Both files are weighted to MODIS and SeaWiFS bands. This includes the MODIS total and in-band weighted data. These data are now available on the MOBY web site.

MLML personnel have begun rewriting all of the MOBY processing software. The new software is more flexible and the data files are organized more efficiently. The current algorithm used to process will not be changed; however, when old deployments are reprocessed, the values may change slightly. In addition, the diver calibration data from deployments 3 through 14 were reprocessed. Also, the MOBY homepage will be updated with frames to make viewing data easier.

MOS/SIS

Mike Feinholz continues to process data from instrument calibrations and from shipboard MOS and SIS profiles using MATLAB programs customized at MLML. During MOBY-L59 in August, two MOS/SIS profiles were performed at station 02 coincident with MOBY214 and SeaWiFS observations, and three profiles at station 03 coincident with MOBY and MODIS observations. MOS water-leaving radiances are convolved with SeaWiFS and MODIS spectral band responses for integration with our bio-optical data base (see Appendix 2 for a MOS station summary).

FOS

The data processing software for the FOS was completed. The software allows the user to create system response files, dark scan files, process and error check the data, and calculate derived products. The Graphical User Interfaces (GUI's) allow users with limited MATLAB experience to easily and interactively check the data. Users with minimal experience with MATLAB have given the processing software high praise. Non-GUI functions process the data following MLML radiometric protocols. In addition to processing the data, HTML pages are created automatically allowing the user to view the processed data easily.

COMPREHENSIVE DATABASE

The work is continuing on the comprehensive database which includes pigment, total suspended material and radiometric data from the CZCS Era to present. MOCE-6 cruise data are being added to the database.

PIGMENTS

In August and September 2000, CHORS personnel performed quality assurance and quality control (QA/QC) on HPLC chromatograms for samples analyzed in June 2000. This included the analysis of system blanks, spiked blanks and various pigment standards, in which the HPLC system response factor for each pigment compound was calculated as the slope of the regression of the peak areas of the parent pigment against the pigment concentration of the injected working standards.

In September, pigment samples from two MOBY cruises were analyzed by the HPLC system.

The HPLC system was recalibrated, using a pigment standard and checked for linearity and stability prior to the analysis of the samples. Four samples from MOBY-L58 and 30 samples from MOBY-L59 were analyzed.

In October, CHORS personnel delivered the HPLC data from the MOCE 6 and MOBY-L54 cruises. Comparisons between HPLC and fluorometrically determined chlorophyll *a* and total accessory and total chlorophyll *a* have been made. Similar trends were found during these cruises as had been found previously for other cruises around the MOBY Mooring site.

INSTRUMENT DEVELOPMENT

MOS

The replacement MOS housing tubes supplied by JDF were deemed unusable due to poor quality in the raw material and flaws in the welding were made worse by the anodizing process. The replacement MOS housing tubes have been fabricated at the University of Hawaii Marine Center and are being sent to the plater for anodizing.

MOBY

We completed fabrication of three replacement MOBY Spar assemblies. The final fit and foam work was completed in November. The first of the new units is in use on MOBY deployment M215.

MOBY Mooring

Replacement Mooring components are on order in preparation for the March 2001 replacement cruise. Mooring Systems personnel are scheduled to assist in the March mooring deployment cruise.

FOS

Mark Yarbrough is currently working to integrate the instrument data output, improve the dark performance, and acquire much needed spare fiber optic components. A multiple serial I/O hardware and software are needed to allow integration of the ancillary data streams within the instrument. A miniature multiple serial I/O expansion board for the Persistor controller recently became available and is on order. Improvements to the power supply/TE cooler system will require a change to the physical coupling of the TE cooler to the array. The existing cooler arrangements do not work well. The backside of the array is not as near to the end plate of the spectrograph as we had earlier thought. The array is also insulated from the cooler by the detector pre-amp board. The array however is well coupled thermally to the spectrograph housing. The existing cooler arrangements chill the entire end of the spectrograph case, which likely does more to create an unwanted thermal gradient as it does to cool the detector array. We are going to obtain a Hamamatsu detector array with an integral TE cooler for the purpose of designing an improved cooling system.

Aurora optics has found a supplier of fiber optic connectors of the type we require for FOS and MOBY. New connectors and bulk fiber are on order. Replacement fiber sets for FOS will be fabricated as soon as the required lengths can be specified.

WARS

During the MOBY-L59 replacement cruise, the WARS hard drive was damaged. Several weeks after the cruise were spent trying to recover data from the hard drive. When this proved unsuccessful, most of November was spent installing a new hard drive and new software on the system in preparation for the MOCE-7 cruise. After much work in rebuilding the system, WARS was calibrated and worked perfectly during MOCE-7.

Satlantic Profiling Radiometer System

We recently ordered a 14 channel Micro-Pro radiometer system from Satlantic Inc. The new system consists of a lightweight free fall profiler, surface reference, and 12 volt powered deck unit. Sea and deck cables as well as new data acquisition and processing software are included in the package. This system is purchased as an upgrade to the existing SPRM system. We must return the old system after we take delivery of the Micro-Pro. Delivery is expected in February 2001. We should be able to operate both systems during the March cruise for inter-comparison.

MOBY Weather Station

The upgraded Mooring Weather Station System is on order from Coastal Climate Company. The Zeno based system, currently under development at Coastal, consists of the basic weather sensors: wind speed/direction (redundant sensors), air temperature, humidity, barometric pressure, and integration for additional sensors. We intend to add an S4 current meter at 8 meters depth, a surface conductivity/temperature and a fluorometer. The underwater sensors (except the current meter) will be accessible for service from the surface. Based upon prior experience, the S4 needs little service and needs only periodic cleaning by divers. Costal Climate Company has already missed their delivery date, so it is possible the new system will be unavailable for the next Mooring deployment. If that is the case, we will need to redeploy the controller from the existing Mooring. Preparation of the new mooring float will be performed with this option in mind. MSI will be performing the mechanical modifications to the surface float to accommodate the underwater sensors and the additional anemometer mount. MSI will perform these tasks in Hawaii when they come out for the March mooring deployment cruise.

PUBLICATIONS AND MEETINGS

Four scientific symposiums took place during the reporting period that required a considerable effort from the MOCE Team. The NOAA/MOBY site at Snug Harbor hosted an open-house during the IGARSS Honolulu conference on 27 July. Stations were setup to display and explain scientific operations including: MOBY calibrations, WARS and FOS sampling, CTD, MOS, and SIS shipboard deployments, shipboard long-track data acquisition for meteorological, fluorescence, transmittance, particle size, spectroscopy, and pigment analyses.

The Ocean from Space Venice 2000 conference in Venice, Italy, October 9 - 13, saw several poster/papers addressing MOBY issues. The poster's titles are: "Marine Optical Buoy (MOBY) Ocean Color Calibration/Validation Time Series (1997-2000)" (Dennis K Clark**,** Mark A. Yarbrough, Michael E. Feinholz, Stephanie J. Flora, William A. Broenkow, and Yong Sung Kim); "MOBY Absolute Calibration and Stability Time Series" (M..E.Feinholz, M.A.Yarbrough, S.J Flora); "Radiometric Characterization and Calibration of the Marine Optical System (MOS) For the Marine Optical Buoy (MOBY) Project" (C. Habauzit, S.W. Brown, B.C. Johnson, M..Yarbrough, M. Feinholz, & D.K Clark); "Assessment of the Accuracy of the MOBY Spectral Radiance Calibration Sources Using the SXR and the VXR" (B.C.Johnson, H.W.Yoon, M.Feinholz, & D.K Clark).   Dennis Clark made a presentation titled "Initial Bio-Optical Algorithms for MODIS" (D.K Clark, C. Trees, M.E.Feinholz, & M.A. Yarbrough).

Posters were presented at Ocean Optics XV conference in Monaco, October 16 - 20 2000: "A Prototype Fiber Optic Spectrometer System for Limiting Instrument Self-Shading Uncertainties" (D.K Clark, M.A. Yarbrough); "Particulate Absorption and CDOM Measurements Coordinated with Ocean Color Imagery" (M. Yuen).

Dennis K Clark attended a Characterization and Radiometric Calibration for Remote Sensing Conference in Logan, Utah, September 19 - 22, 2000. He gave a presentation titled "Calibration Support for Terra's Moderate Resolution Imaging Spectrometer Sensor with Marine Optical Buoy and Shipboard Observations".

MOCE Team Activities

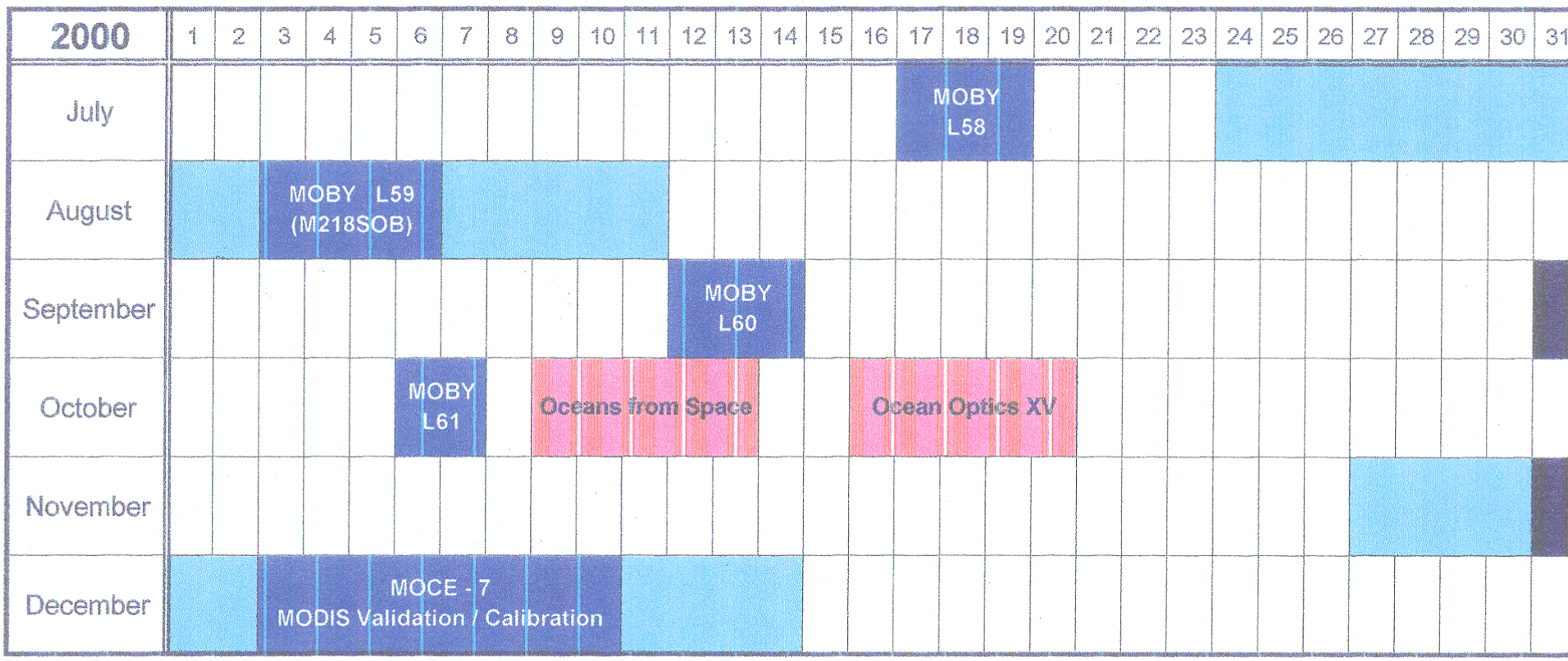


FIGURE 1.

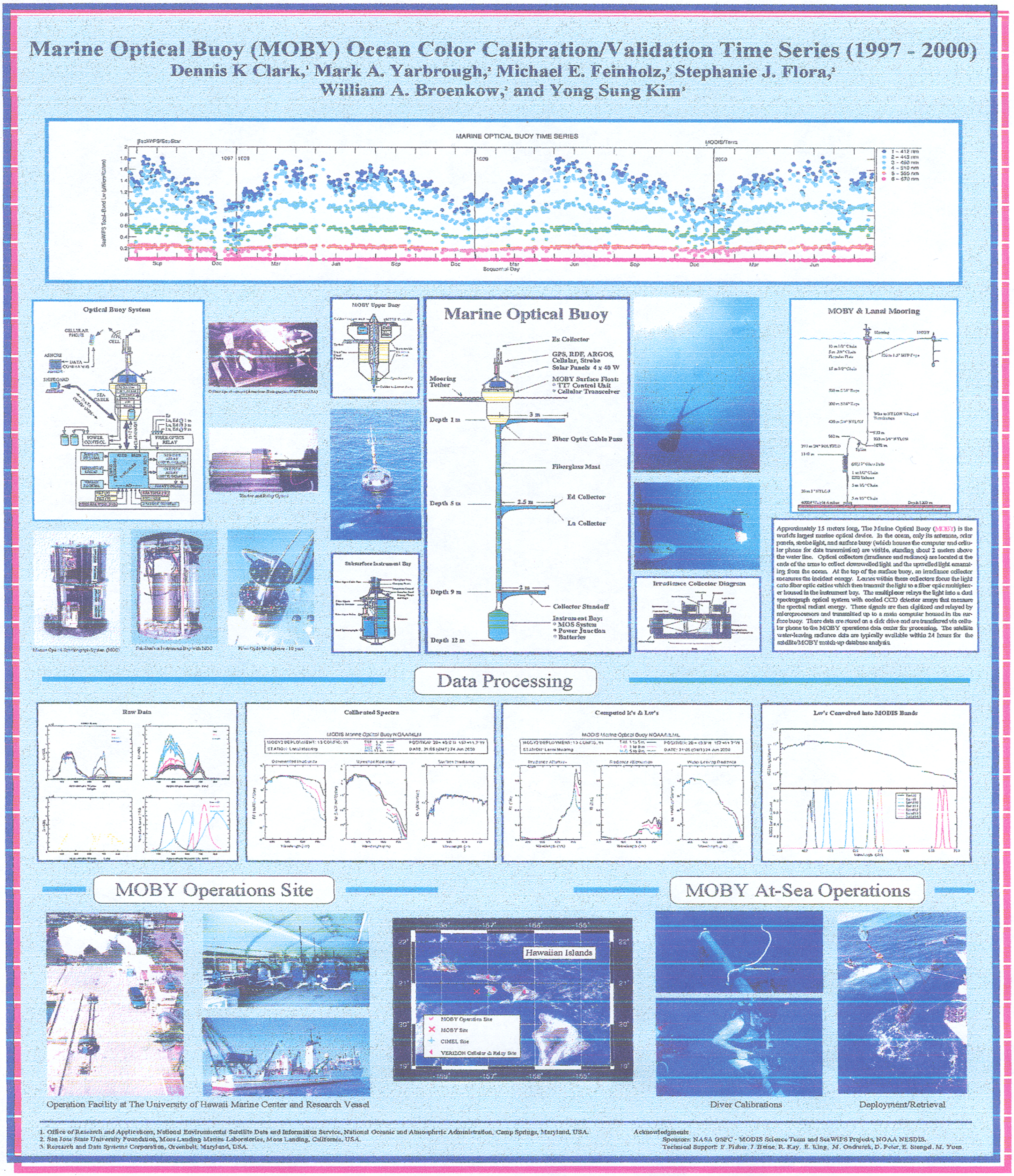

Marine Optical Buoy (MOBY) Ocean Color Calibration/Validation Time Series (1997 - 2000)
Dennis K Clark,[1] Mark A. Yarbrough,[2] Michael E. Feinholz,[2] Stephanie J. Flora,[2]
William A. Broenkow,[2] and Yong Sung Kim[3]
MARINE OPTICAL BUOY TIME SERIES
SeaWiFS/SeaStar
MODIS/Terra
Sequential Day
Optical Buoy System
Marine Optical Buoy
Es Collector
GPS, RDF, ARGOS, Cellular, Strobe
Solar Panels 4 x 40 W
MOBY Surface Float:
TT7 Control Unit
Cellular Transceiver
Mooring Tether
Depth 1 m
3 m
Fiber Optic Cable Pass
Fiberglass Mast
Depth 5 m
2.5 m
Ed Collector
Lu Collector
Depth 9 m
2 m
Collector Standoff
Instrument Bay:
MOS System
Power Junction
Batteries
Depth 12 m
MOBY Upper Buoy
Subsurface Instrument Bay
MOBY & Lanai Mooring
Irradiance Collector Diagram
Approximately 15 meters long, The Marine Optical Buoy (MOBY) is the world's largest marine optical device. In the ocean, only its antennae, solar panels, strobe light, and surface buoy (which houses the computer and cellular phone for data transmission) are visible, standing about 2 meters above the water line. Optical collectors (irradiance and radiance) are located at the ends of the arms to collect downwelled light and the upwelled light emanating from the ocean. At the top of the surface buoy, an irradiance collector measures the incident energy. Lenses within these collectors focus the light onto fiber optic cables which then transmit the light to a fiber optic multiplexer housed in the instrument bay. The multiplexer relays the light into a dual spectrograph optical system with cooled CCD detector arrays that measure the spectral radiant energy. These signals are then digitized and relayed by microprocessors and transmitted up to a main computer housed in the surface buoy. There data are stored on a disk drive and are transferred via cellular phone to the MOBY operations data center for processing. The satellite water-leaving radiance data are typically available within 24 hours for the satellite/MOBY match-up database analysis.
Data Processing
Raw Data
Calibrated Spectra
Computed K's & Lw's
Lw's Convolved into MODIS Bands
MOBY Operations Site
Hawaiian Islands
MOBY Operations Site
MOBY Site
CIMEL Site
VERIZON Cellular & Relay Site
MOBY At-Sea Operations
Operation Facility at The University of Hawaii Marine Center and Research Vessel
Diver Calibrations
Deployment/Retrieval
1. Office of Research and Applications, National Environmental Satellite Data and Information Service, National Oceanic and Atmospheric Administration, Camp Springs, Maryland, USA.
2. San Jose State University Foundation, Moss Landing Marine Laboratories, Moss Landing, California, USA.
3. Research and Data Systems Corporation, Greenbelt, Maryland, USA.
Acknowledgements
Sponsors: NASA GSFC - MODIS Science Team and SeaWiFS Projects, NOAA NESDIS.
Technical Support: F. Fisher, J. Heine, R. Kay, E. King, M. Ondrusek, D. Peter, E. Stengel, M. Yuen.

FIGURE 2.

MOBY ABSOLUTE CALIBRATION AND STABILITY TIME SERIES

Michael E. Feinholz, Mark A. Yarbrough, Stephanie J. Flora : Moss Landing Marine Laboratories, 8272 Moss Landing Road, Moss Landing, CA 95039

Summary :

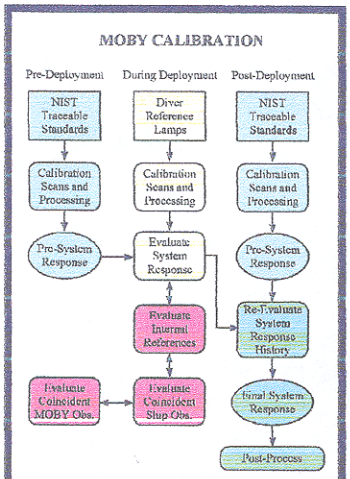
1.) Spectral radiances of MOBY calibration sources accurate to within +/- 3 % from 412 to 870 nm

2.) Internal Reference stability average ~ 1 %

3.) Diver References (relative to initialization) average: Lu +/- 2 %, Ed < 5 %

4.) System Response during deployment average stability: Lu ~ 2 %, Ed ~ 3 %

5.) Post Processing to include MOS stray-light correction and temperature correction (algorithms under development).



SLM : Standard Lamp Monitor

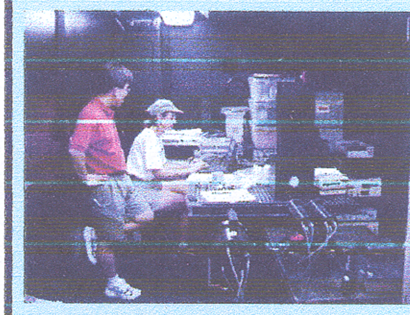
Verification of Standard Sources

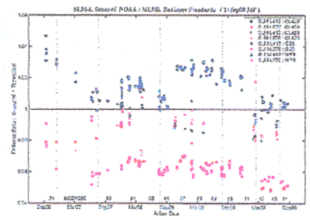
2 Modes : Radiance and Irradiance

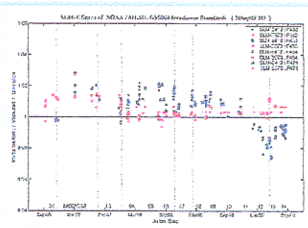
2 Channels : 412 nm and 870 nm

3 NIST Characterizations / Calibrations

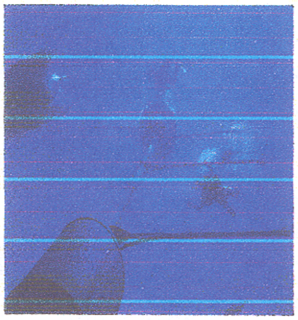
3 NIST Intercomparisons in Hawaii

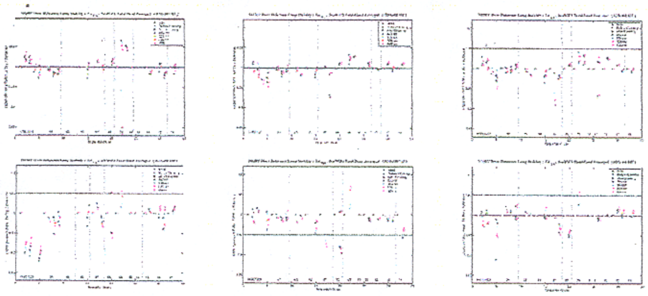




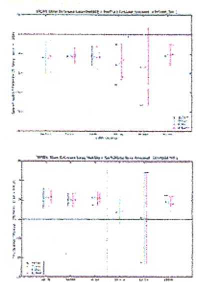


During Deployment : Diver Reference Lamp Scans and Process-

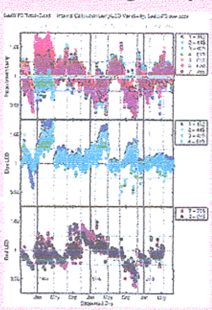


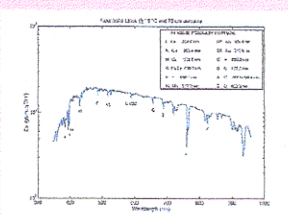


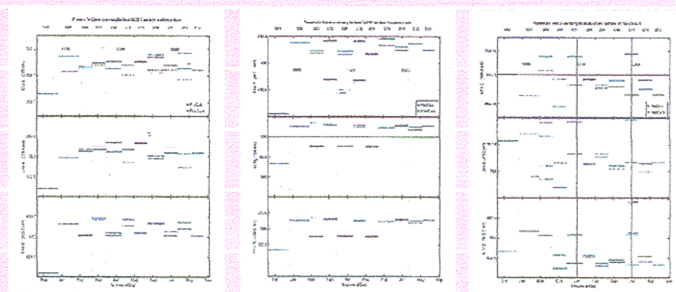
Mean & StDev



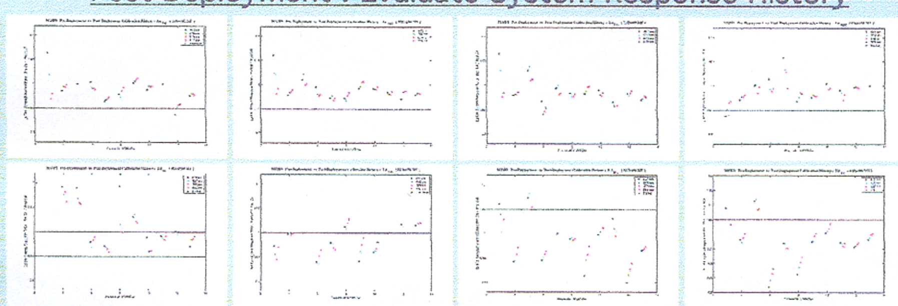
During Deployment : Evaluate Internal References (Incandescent, LEDs) & Fraunhofer



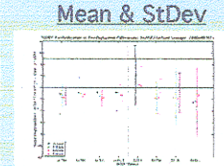




Post Deployment : Evaluate System Response History



Mean & StDev



Acknowledgements

This work was financially supported by the U.S. National Aeronautic and Space Administration (NASA), Goddard Space Flight Center (GSFC), MODIS and SeaWIFS Science Team Projects; and administratively and technically supported by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), National Environmental Satellite, Data, and Information Service (NESDIS), Office of Research and Applications.

FIGURE 3.

A Prototype Fiber Optic Spectrometer System for Limiting Instrument Self-shading Uncertainties

Dennis K Clark[1] and Mark A. Yarbrough[2]

Theoretical Basis

"Self shading of in-water optical instruments."
H.R. Gordon, and K. Ding, 1992
Limnol. Oceanogr, 37, 491-500

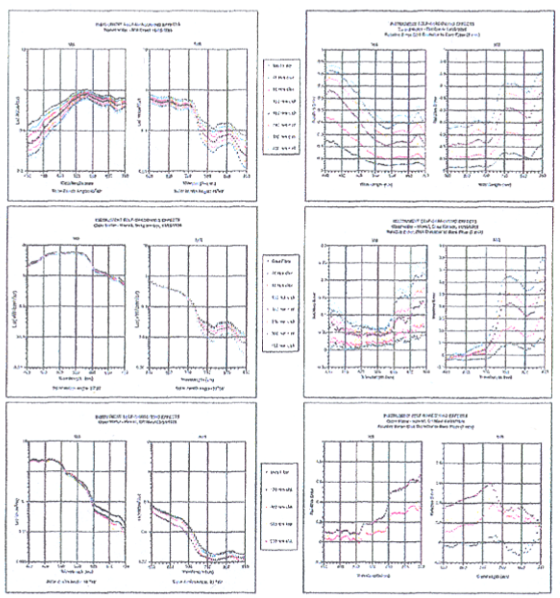
$$L^{*}_{u}(\lambda) = \frac{L^{-}_{u}(\lambda)}{1-\varepsilon(\lambda)} \quad \text{and}$$

$$\varepsilon(\lambda) = 1 - e^{-k'(\lambda)r},$$

where: $L^{*}(\lambda)$ - true value
$L^{-}(\lambda)$ - measured value
$k' = y/\tan\theta_{0w}$
θ_{0w} - refracted solar zenith angle
y - empirical factor ($y \sim 2$)

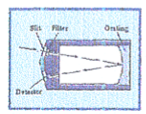
Accurate spectroradiometric measurements of the apparent optical properties within the marine environment over a large spectral range is an extremely challenging task. These systems must have large dynamic ranges and stray light rejections on the order of 10^{12} and 10^{-6}, respectively. An additional constraint must be considered as a result of the modeling work on the effects of instrument self-shading by H. R. Gordon and K. Ding (1992) when making these measurements in spectral regions where attenuation is dominated by absorption processes (i.e. the near-infrared due to water absorption). Experimental fiber optic shadowing measurements by D. Clark, Y. Ge and L. Koval for clear and turbid waters have demonstrated that this effect also contributes major uncertainties in these observations within turbid/eutrophic waters.

Experiment Results

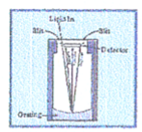


Fiber Optic Spectrometer (FOS)

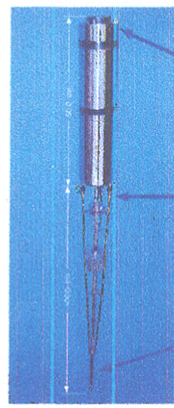
A prototype of a Fiber Optic Spectrometer (FOS) system, for the high absorption cases, has been developed in order to reduce the uncertainties associated with instrument self-shading. This system incorporates two modified American Holographic AH4000 series dual beam spectrometers (visible, f5 and near-infrared, f3.5) housed in a cylindrical, 11.5 x 50 cm, pressure case. These American Holographic dual beam spectrographs are designed to allow simultaneous dispersion of the irradiance and radiance spectra onto a 512 element Hamamatsu self-scanning diode array. Thus, allowing the system to measure the incident surface irradiance, downwelled irradiance, and upwelled radiance at nominal spectral resolutions of 5 nm from 375 to 725 nm and 10 nm from 600 to 1100 nm. The spectrometers are coupled to the radiance and irradiance collectors with 1.0 mm and 0.10 mm silica/silica glass fibers, respectively. The radiance collector fibers can be displaced 0.5 to 1.5 m from the instrument housing, via a dual optical pressure housing feed through, to further reduce shading effects. The incident surface irradiance is acquired only during the near-surface radiance measurements. The preliminary results from the marine optical experiment conducted in the Gulf of California (October 1999) for a turbid and clear water stations are presented.

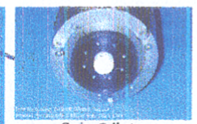


Side view of the MD5 optical module (American Holographic)[4]

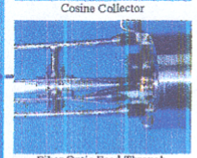


MD5 Optical schematic showing wavelength distribution over the diode array. (American Holographic)[4]

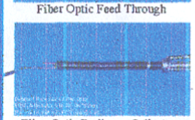




Cosine Collector



Fiber Optic Feed Through

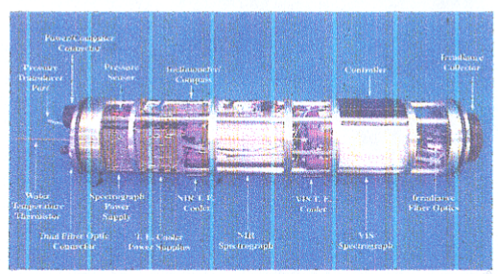


Fiber Optic Radiance Collectors

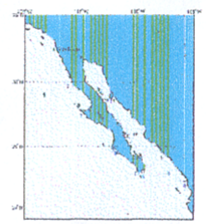
Spectrograph Specifications	VIS	NIR
Model	AH4230	AH4540
Wavelength Range	375 - 725 nm	600 - 1100 nm
Slit	50 um X 2.5 mm	100 um X 2.5 mm
Focal Length	f5	f3.5
Nominal Resolution	[illegible]	[illegible]
Bandpass FWHM	5 nm	[illegible]

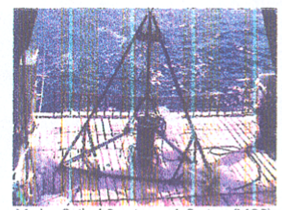
Ancillary Sensors	Range	Resolution	Accuracy
Depth	0 to 100	0.030	0.02 Meters
VIS Detector temperature	-10 to 100	0.002	0.05 °C
NIR Detector temperature	-10 to 100	0.002	0.05 °C
Water temperature	-10 to 100	0.002	0.05 °C
Internal temperature	-40 to 85	0.031	0.5 °C
Azimuth	0 to 360	0.020	<1 Degrees
Pitch/Roll	±70	0.017	<0.02 Degrees

Dimensions	
Diameter	114 mm
Length	500 mm
Instrument weight	4.8 Kg (in water)
With frame and ballast	8.9 Kg (in water)
Self-shading	0.01 εr with 1.0 meter Radiance fiber
	0.04 εr with 0.5 meter Radiance fiber

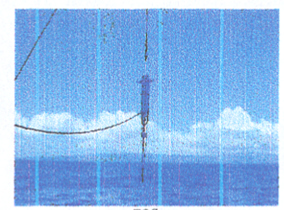


MOCE 5 Initial Observations



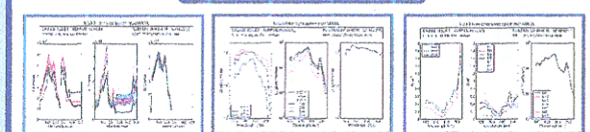


Marine Optical Spectrograph System (MOS)

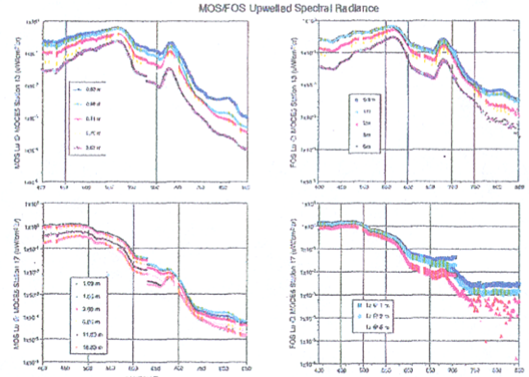


FOS

Data Processing



MOS/FOS Upwelled Spectral Radiance



1. Office of Research and Applications, National Environmental Satellite Data and Information Service, National Oceanic and Atmospheric Administration, Camp Springs, Maryland, USA.
2. San Jose State University Foundation, Moss Landing Marine Laboratories, Moss Landing, California, USA.

Acknowledgments
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Technical Support: Y.S. Kim, E. King, L. Koval.

Reference:
3. H.R. Gordon and K. Ding, 1992. Limnol. Oceanogr, 37, 491-5000.
4. J.T. Brownigg, Design and Performance of a Miniature Dual-Beam Diode-Array Spectrometer. American Holographic, Inc.

FIGURE 4.

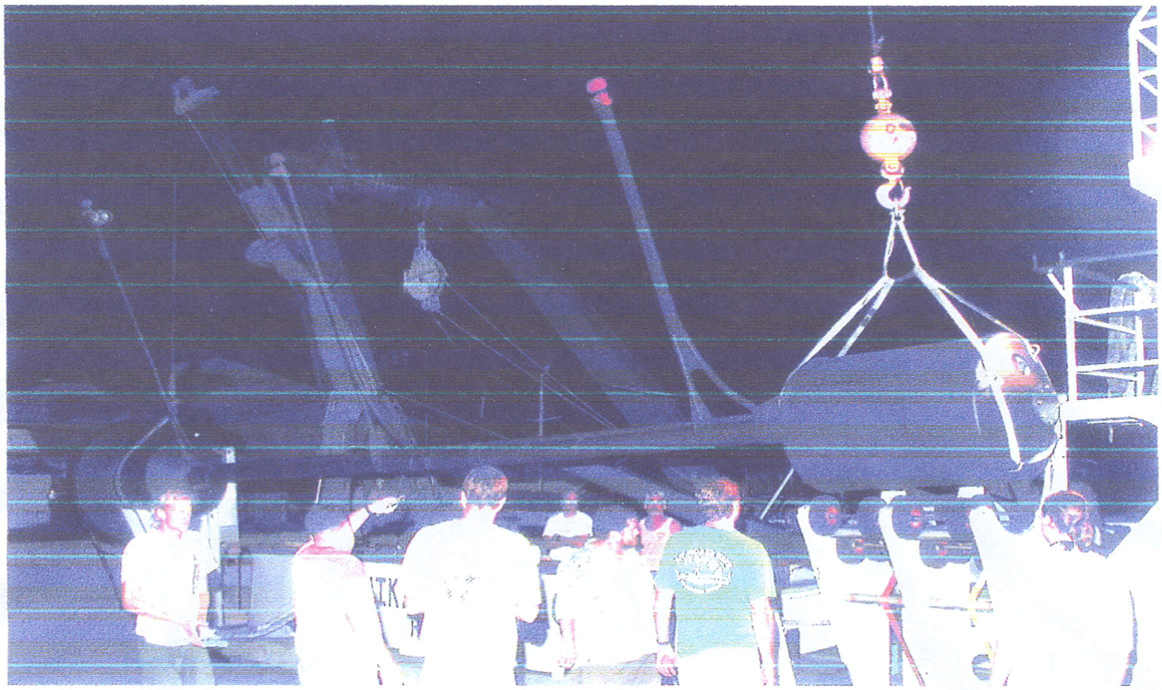

FIGURE 5.

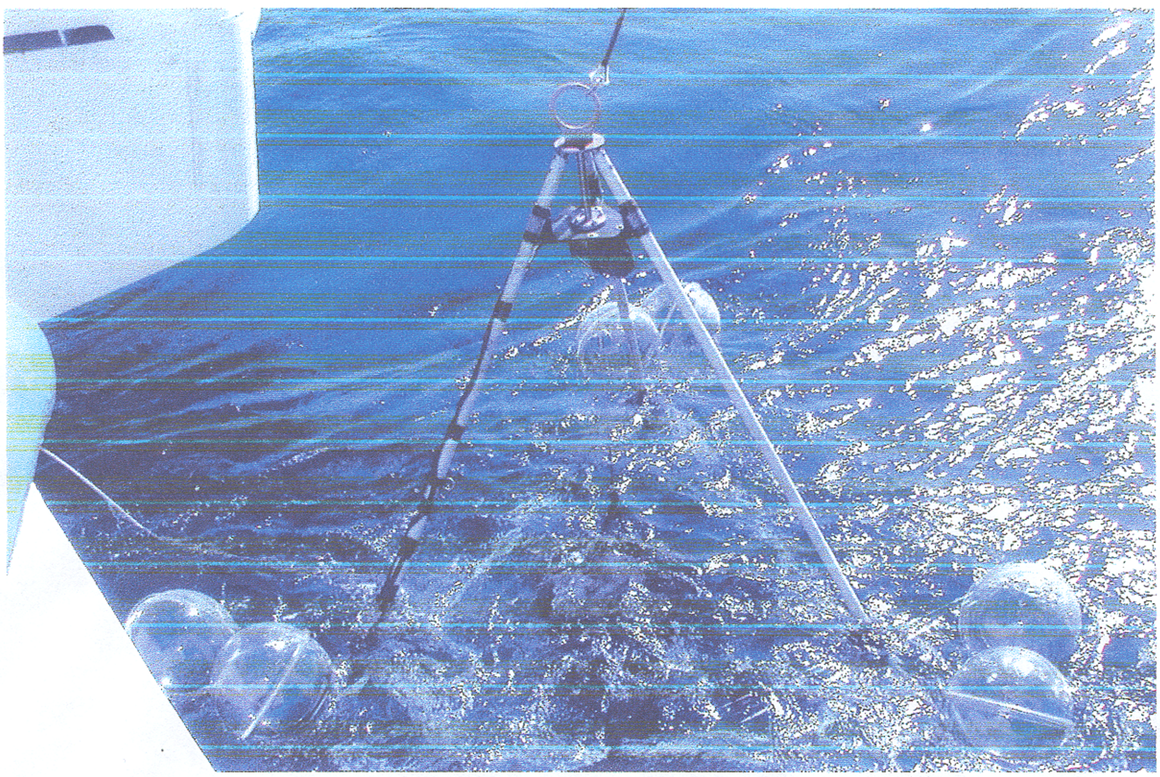

FIGURE 6.

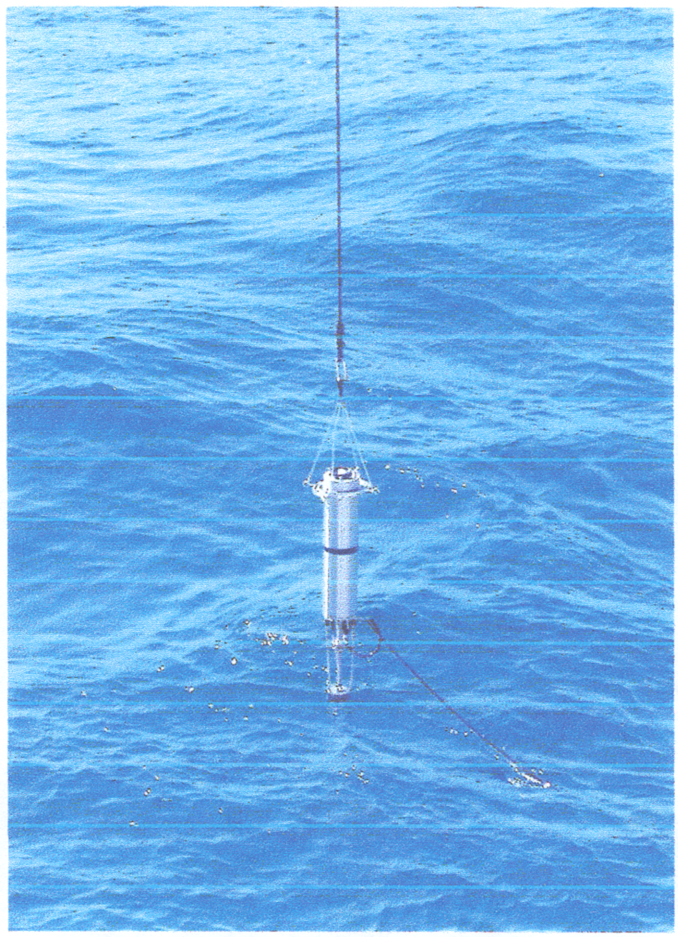

FIGURE 7.

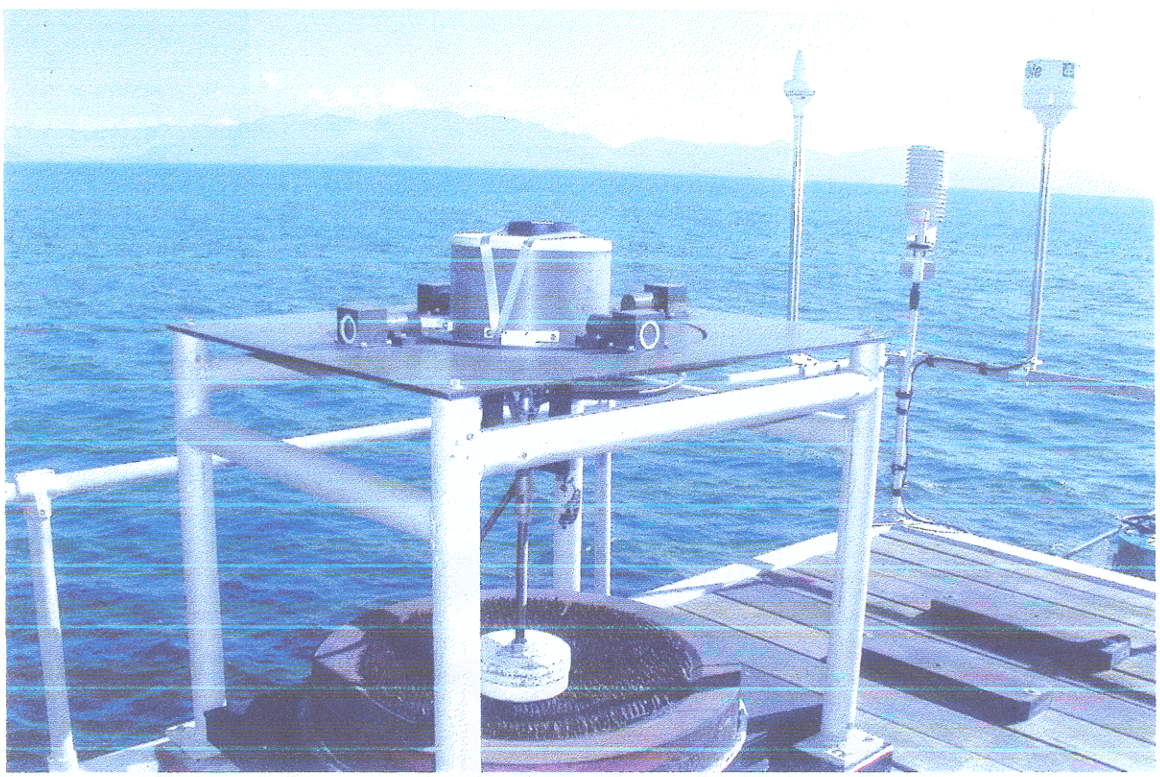

FIGURE 8.

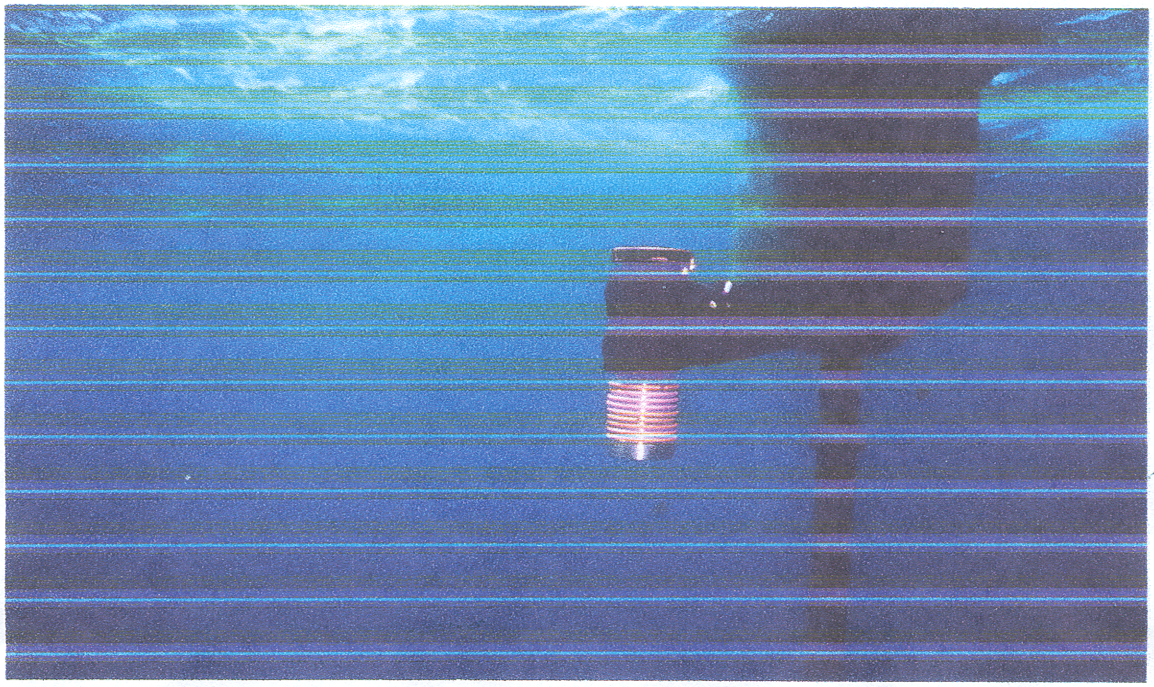

FIGURE 9.

APPENDIX 1 : MOCE-7 SeaBird CTD Stations

Station	Position	Date (GMT)	Filename	Max. Depth
01, Diamond Head	21° 07.20'N 157° 45.64'W	22:52 (GMT) 03 Dec 2000	sbe0137p.mld	205
02, Maui Triangle	20° 54.08'N 156° 47.68'W	22:05 (GMT) 05 Dec 2000	sbe0138p.mld	70
03, Pokai Bay	21° 23.35'N 158° 21.99'W	19:47 (GMT) 06 Dec 2000	sbe0139p.mld	204
04, South of MOBY	20° 27.57'N 156° 59.02'W	22:36 (GMT) 07 Dec 2000	sbe0140p.mld	205
05, EDA	21° 24.54'N 158° 27.86'W	20:33 (GMT) 08 Dec 2000	sbe0141p.mld	205
06, Kahoolawe	20° 29.71'N 156° 57.07'W	23:59 (GMT) 09 Dec 2000	sbe0142p.mld	207
07, Pokai Bay 2	21° 24.23'N 158° 22.75'W	19:36 (GMT) 10 Dec 2000	sbe0143p.mld	204

Ap. 1

APPENDIX 2 : Calibrations and maintenance schedules for MLML standards and instruments

• SLM
12-Jul-2000 Pre-L59 : OL420-S3W5D100 after MOS204cfg04 UP Lu
19-Jul-2000 Pre-L59 : OL420-S3W5D100 after MOS202cfg08 UP Lu
20-Jul-2000 Pre-L59 : GS5000-F471 after MOS202cfg08 & SIS101cfg04
21-Jul-2000 Pre-L59 : GS5000-F453 after MOS202cfg08 & SIS101cfg04
29-Jul-2000 Pre-L59 : OL420-S3W6D40 after MOBY214 LuB,M,T
30-Jul-2000 Pre-L59 : OL420-S3W6D40 after MOBY214 LuB,M,T
02-Aug-2000 Pre-L59 : GS5000-F453 after MOBY214 EdB,M,T,S
03-Aug-2000 Pre-L59 : GS5000-F453 after MOBY214 EdM
16-Aug-2000 Pos-L59 : GS5000-F453 after MOBY213 EdB,M,T,S
18-Aug-2000 Pos-L59 : OL420-S3W6D40 after MOBY213 LuB,M,T
10-Nov-2000 Pos-L59 : OL420-S3W5D100 be&aft MOS205cfg05 UP Lu
15-Nov-2000 Pos-L59 : OL420-S3W5D100 be&aft MOS202cfg08 UP Lu
16-Nov-2000 Pos-L59 : GS5000-F453 be&aft MOS202cfg08 & SIS101cfg04 Ed
29-Nov-2000 Pre-MOCE7 : OL425-S3W6D100 after MOBY215 LuB,T
30-Nov-2000 Pre-MOCE7 : OL425-S3W6D100 after MOBY215 LuB,M,T

• SIS101
20-Jul-2000 PosL56 : GS5000-F471 {19Jun97 NIST Cal#1}
21-Jul-2000 PreL59 : GS5000-F453 {29Jul98 NIST Cal#2}
16-Nov-2000 PosL59/PreMOCE7 : GS5000-F453 {29Jul98 NIST Cal#2}

• MOS202
20-Jul-2000 PosL56 : OL420-W5D100, GS5-F471, HgA, Ne
21-Jul-2000 PreL59 : OL420-W5D100, GS5-F453, HgA, Ne
16-Nov-2000 PosL59/PreMOCE7 : OL420-W5D100, GS5-F453, HgA, Ne

• MOS204
Cfg04 = 00-Jul-2000 PreL59 CCD Heads pumped, coolant pump serviced
12-Jul-2000 PreL59 : UP Lu via OL420-S3W5D100, HgA, Ne

• MOS205
13-Nov-2000 PosL59 : UP Lu via OL420-S3W5D100, HgA, Ne <Pos-MOBY213>